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SATURABLE ABSORBING QUANTUM WELLS AT 1.55 MICRON

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Rome Laboratory
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13. ABSTRACT *(Maximum 200 words)*
Multiple Quantum Well structures are grown on indium phosphide substrates by molecular beam epitaxy (MBE). These are designed to generate photoluminescence and a saturable absorbing edge at 1.55 um. Samples of various concentrations are grown and spectrally characterized. Suitability as an erbium fiber laser modelocker is being tested at Rome Lab.

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Introduction

Saturable absorbers constructed of semiconductor quantum wells have been successfully employed in mode locking Ti:sapphire lasers. In these applications, the saturable absorbing quantum well sample is positioned inside the laser cavity and passively, *i.e.* without electrical or optical control, causes the laser to mode lock. It was the aim of this project to develop semiconductor quantum wells suitable for mode locking Er^{3+} fiber lasers.

Ti:sapphire lasers operate in the $\lambda \sim 800$ nm range. The appropriate semiconductor material system for saturable absorption at 800 nm is AlGaAs/GaAs. The present application requires saturable absorption at $\lambda \sim 1.55$ μm, which necessitates a different choice of semiconductor materials. There are two reasonably well developed semiconductor material systems for construction of quantum wells with near band edge (saturable) absorption at 1.55 μm, $Al_{0.48}In_{0.52}As/Ga_{0.47}In_{0.53}As$ and $InP/Ga_{0.47}In_{0.53}As$. The molecular beam epitaxy (MBE) system used for the growth of the semiconductor samples for this project has the capability of growing both of these 1.55 μm material systems. The former system is easier to grow since it contains only a single group V element, arsenic; it will be emphasized in the proposed task. The latter material system requires the use of two group V elements, arsenic and phosphorus. If necessary this second material system can be employed.

The primary aim of this project was the growth and evaluation of $Al_{0.48}In_{0.52}As/Ga_{0.47}In_{0.53}As$ quantum well structures for mode locking of Er^{3+} fiber lasers. The effect of MBE growth conditions on the performance of the mode locking ability of the samples was investigated. The low intensity absorption spectra of the samples were measured. After measurement of their cw, linear optical properties samples were delivered to K. Teegarden / R. Erdmann of Rome Labs for mode locking evaluation in an Er^{3+} fiber laser. Additionally, quantum wells consisting of the backup material system, $InP/Ga_{0.47}In_{0.53}As$, were constructed and evaluated.

Description of Samples

During the course of this project, a total of 9 samples were grown by molecular beam epitaxy (MBE). All samples consisted of a 50 periods of 100 Å wells and 100Å barrier layers deposited on InP substrates. The total thickness of the the layers (50 × [100Å + 100Å]) is 1 μm; the nominal substrate thickness is 500 μm.

In all cases the well material is $Ga_{0.47}In_{0.53}As$. Most of the samples had InP barriers, but two had $Al_{0.48}In_{0.52}As$ barriers.

The samples are summarzied in table 1.

sample no.	structure	growth temperature (°C)	absorption edge wavelength (nm)	exciton structure	comments
1298	AlInAs/GaInAs	490	-		unsuccessful growth
1303	AlInAs/GaInAs	490	-		
1305	AlInAs/GaInAs	490	1620	none	grown like 1303, except with higher arsenic flux
1442	InP/GaInAs	430			
1444	InP/GaInAs	430	~1590	very weak	grown like 1442, except shorter phosphorus growth stop
1461	AlInAs/GaInAs	430	1607	none	
1544	AlInAs/GaInAs	520	1645	strong	
1580	AlInAs/GaInAs	445	1624	strong	
1590	AlInAs/GaInAs	405	1617	moderate	grown like 1580, except lower growth temperature

Table 1. Summary of growth parameters and optical transmission spectral characteristics of samples grown for the this project.

CW Linear Optical Spectra of Samples

Transmission spectra

The cw linear optical transmission spectrum of six of the samples were measured with a commercial spectrophotometer. The absorption edge was estimated by visual inspection of the data, and is listed in table 1. Also listed in table is the qualitative strength of the exciton features in the transmission spectra. These six transmission spectra are shown in figures 1 - 6.

Photoluminescence

Room temperature photoluminescence was measured on two of the samples, numbers 1442 and 1444. These two spectra are shown in figure 7.

The spectral dependence of the photoluminescence of #1442 and #1444 are very similar. It is very likely that the absorption edges of the two samples are therefore also very similar.

Thus, although no transmission spectrum was measured on #1442, it is reasonable to assume that the absorption edge of #1442 is also around 1590 nm.

The two spectra were not measured under identical conditions. The spectrometer slits were different for the two measurements, producing different spectrometer throughput. Taking the difference in spectrometer throughput into account, sample #1442 has more intense photoluminescence than #1444 by a factor of 2.25.

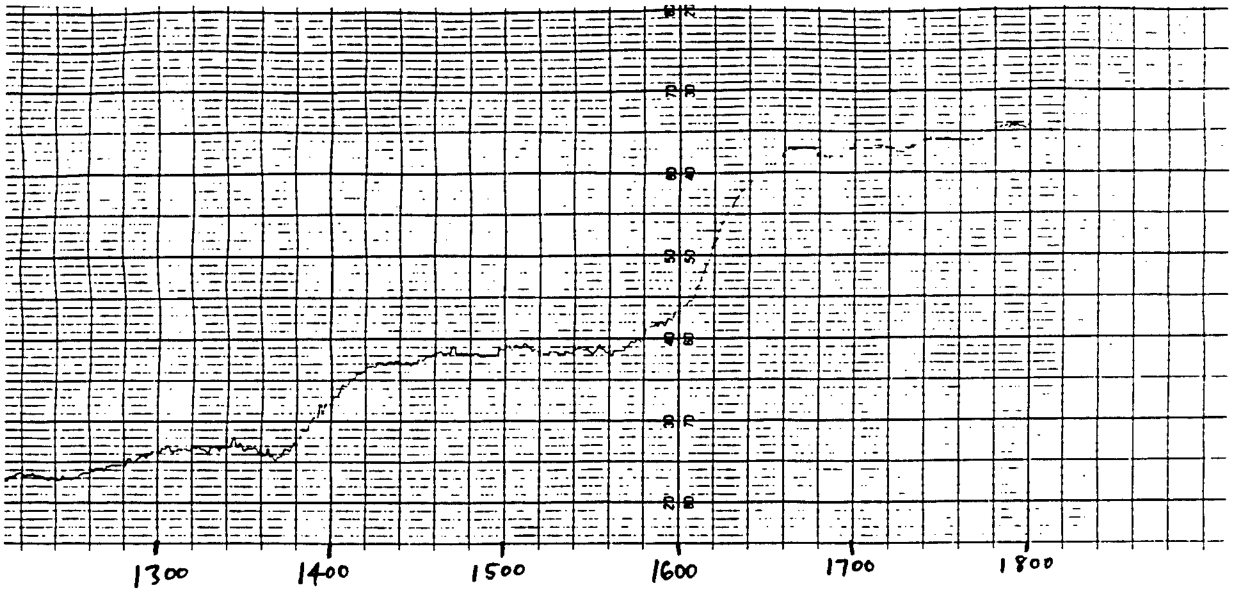

Figure 1. Transmissivity (arb. units) vs. Wavelength (nm) for sample #1305.

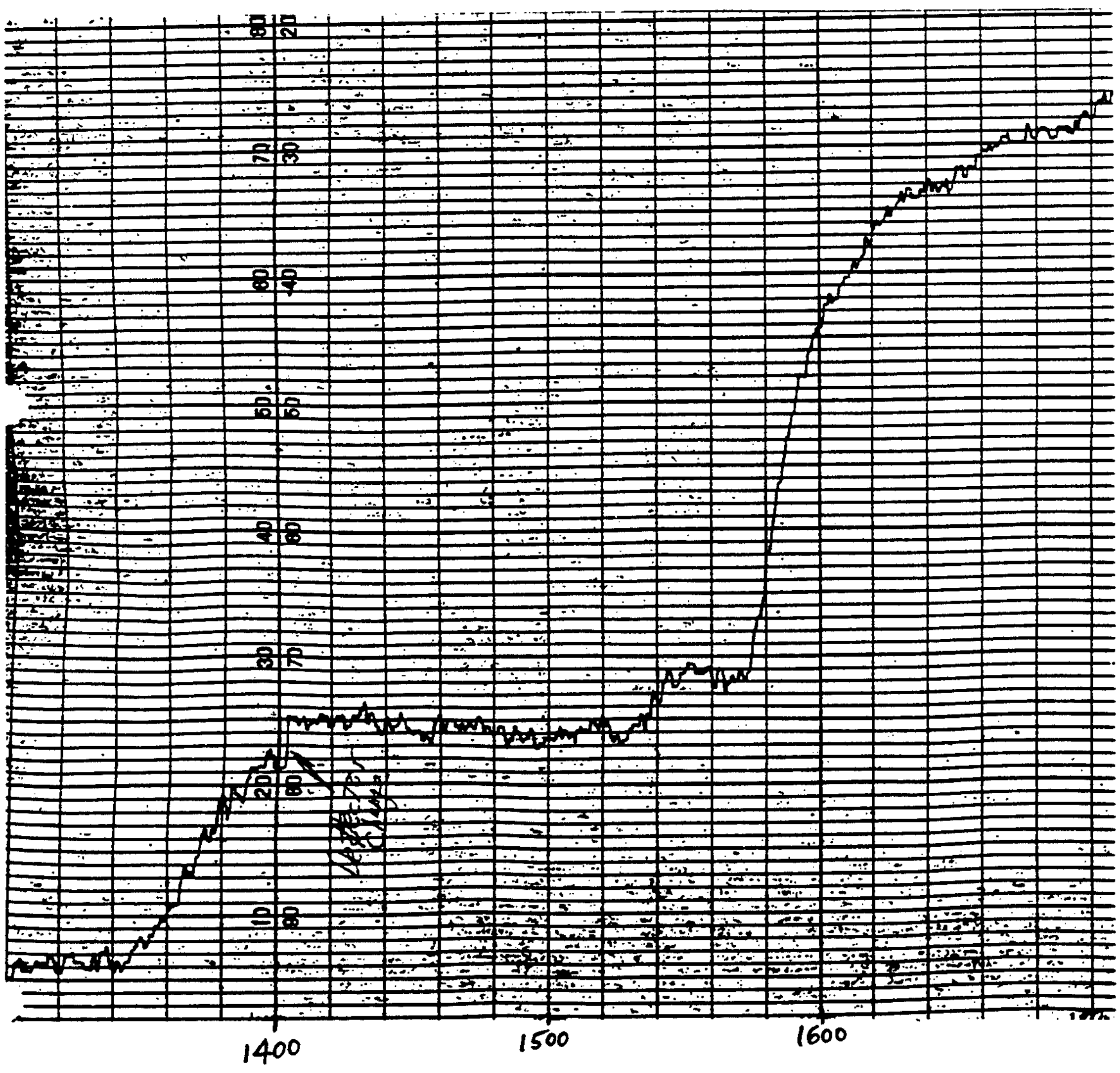

Figure 2. Transmissivity (arb. units) vs. Wavelength (nm) for sample #1444.

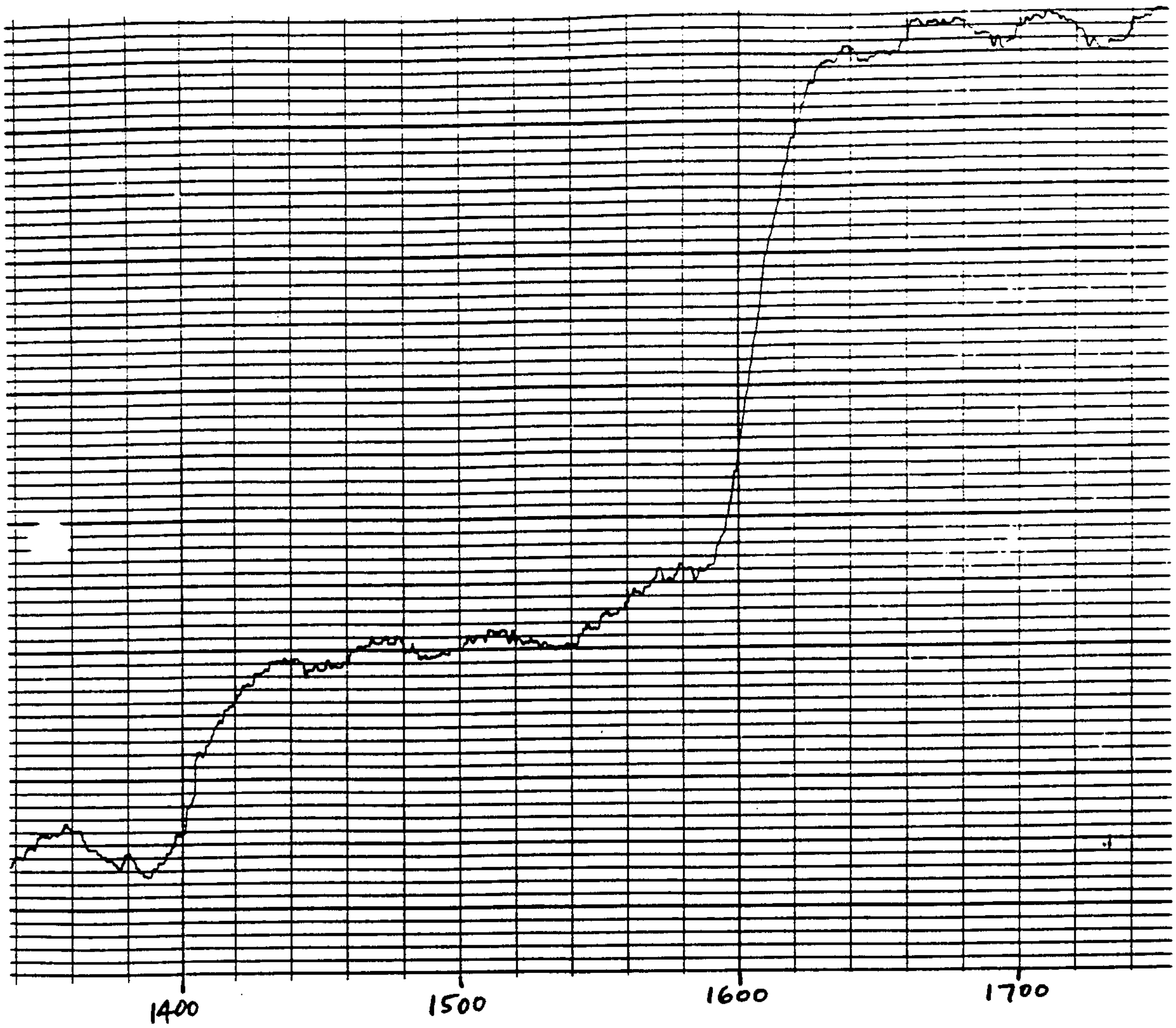

Figure 3. Transmissivity (arb. units) vs. Wavelength (nm) for sample #1461.

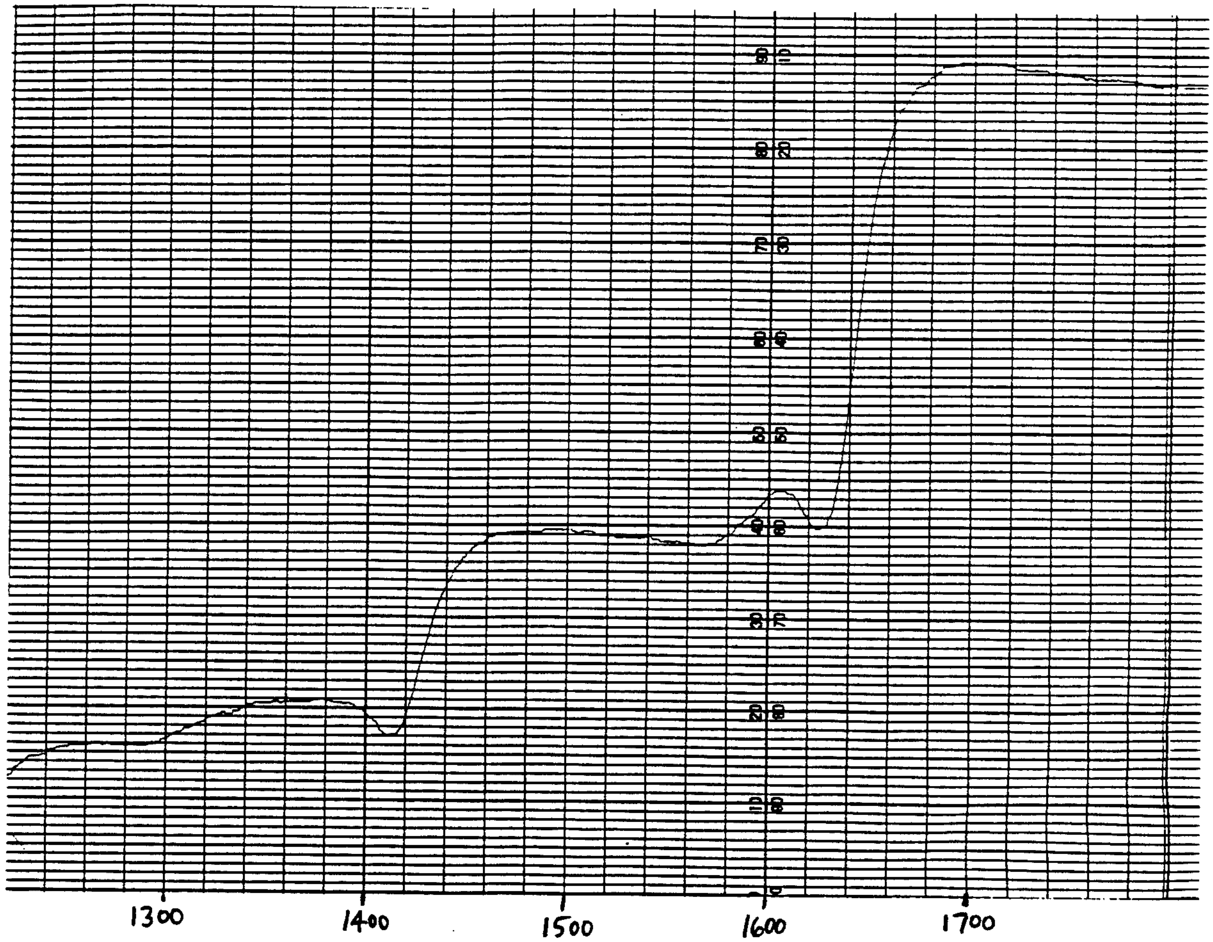

Figure 4. Transmissivity (arb. units) vs. Wavelength (nm) for sample #1544.

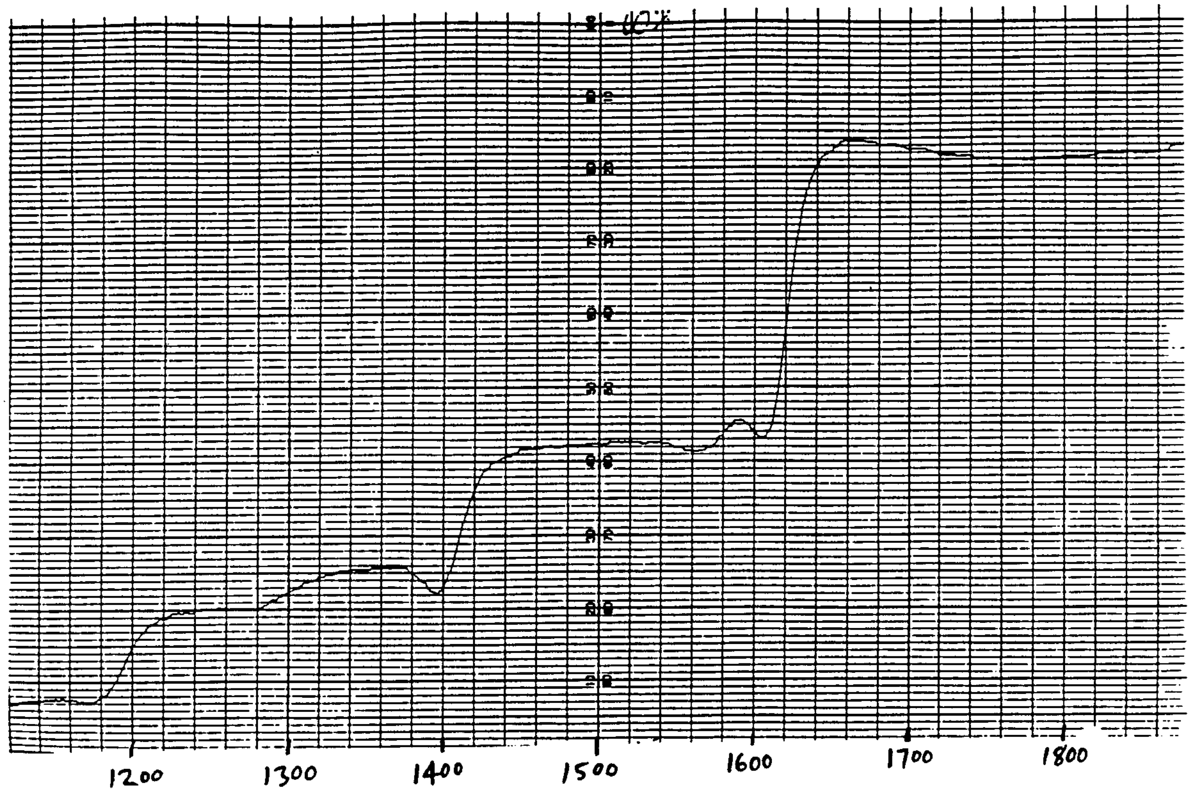

Figure 5. Transmissivity (arb. units) vs. Wavelength (nm) for sample #1508.

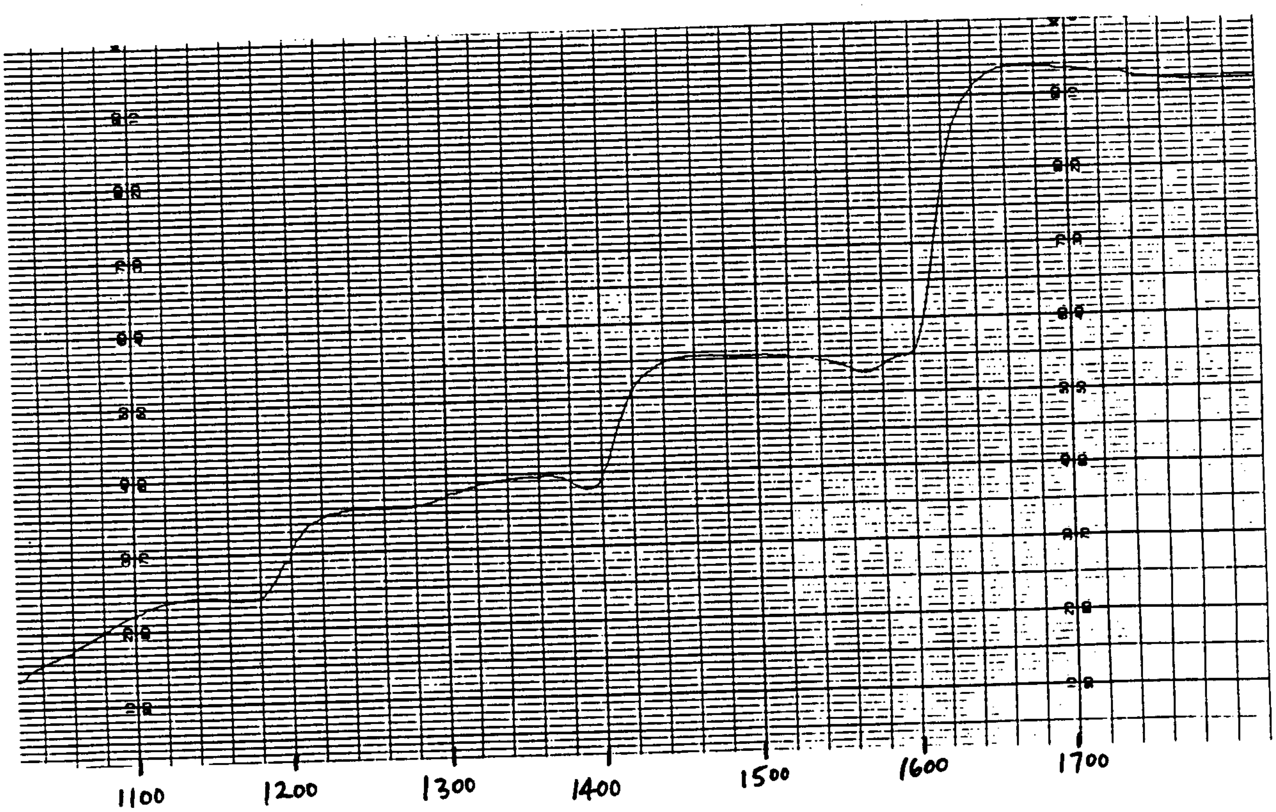

Figure 6. Transmissivity (arb. units) vs. Wavelength (nm) for sample #1590.

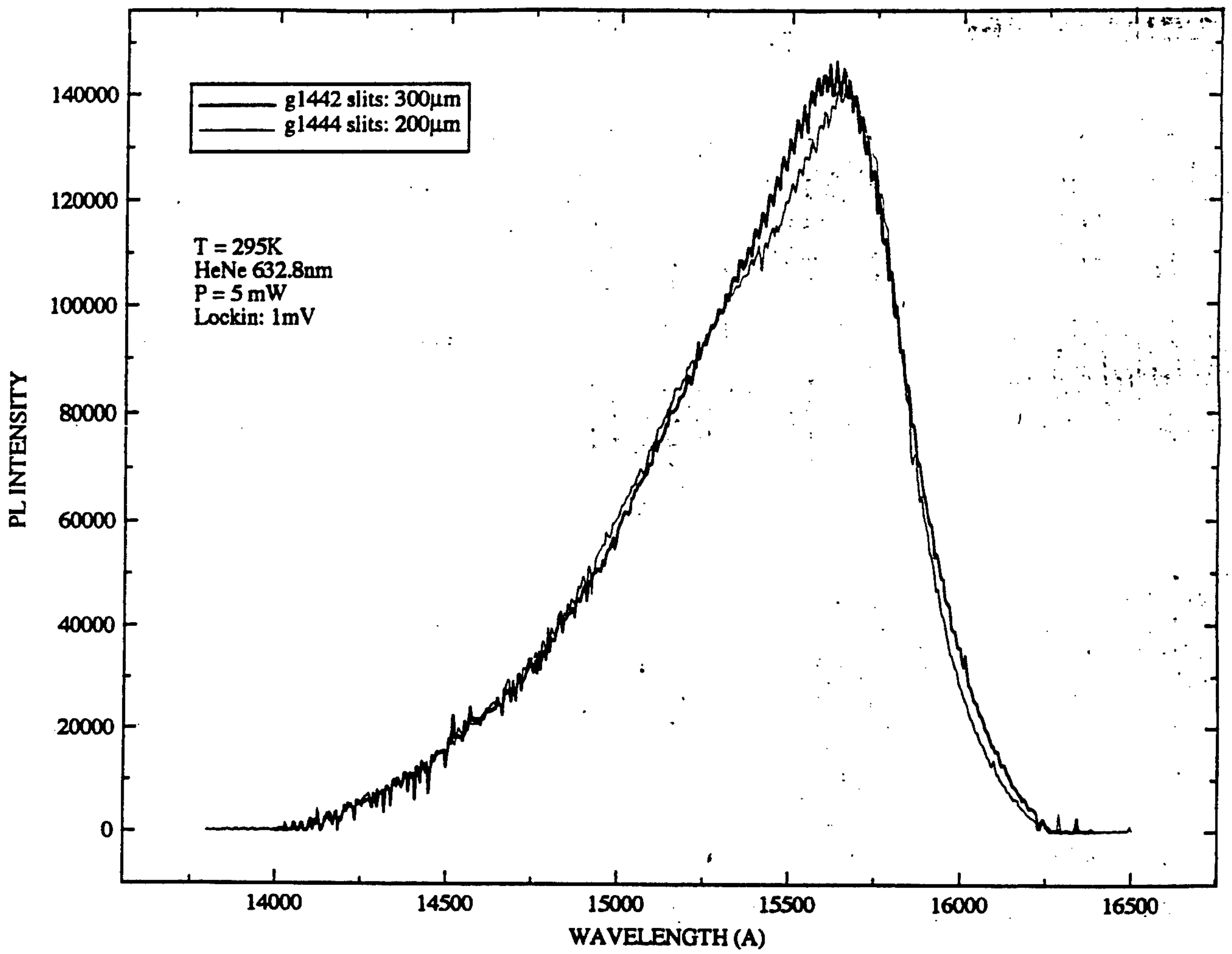

Figure 7. Photoluminescence Spectra of samples #1442 and #1444.

Discussion of data

This project concentrated on investigating two main sample parameters that would affect the use of these samples for mode locking fiber lasers. The first parameter is the wavelength of the absorption edge. The absorption edge, and essentially the entire absorption spectrum, can be shifted in wavelength by adjusting through the quantum well thicknesses and compositions. As the absorption edge is moved to longer and longer wavelengths beyond the lasing wavelength, the sample's linear absorption at the lasing wavelength becomes stronger and, presumably, the saturation intensity of the sample becomes larger.

A second characteristic of the sample which is important in saturable absorbing applications, is the carrier lifetime. Presumably, as the carrier lifetime becomes shorter, the saturation intensity of the sample increases. The carrier lifetime in these samples is probably dominated by non-radiative recombination. The density of non-radiative recombination centers is affected by the several different parameters of the MBE growth, growth temperature being the primary parameter. This density of non-radiative recombination centers is difficult to measure directly, but can be qualitatively indicated by the strength of exciton features in the transmission spectrum and by photoluminescence intensity. Both of these types of measurements were performed in this project, with emphasis placed on the exciton absorption. It was found that the strength of the exciton absorption decreased, and presumably the saturation intensity increased, as the MBE growth temperature decreased.

The main activity of the project is the construction of quantum well samples that absorb at 1.55 μm, and the investigation of how the linear absorption properties can be affected by the way in which the MBE growth is carried out. A suggested second stage of this topic would be an investigation of how the non-linear (saturable) absorption is affected by the way in which the MBE growth is carried out. Apparently some of these non-linear measurements are already under way at Rome Laboratory.

Conclusions

It has been demonstrated in this project that quantum well structures with saturable absorption near 1.55 μm can be grown by MBE. The MBE growth conditions used to produce the quantum well sample have significant effects on the linear and nonlinear optical properties of the samples. Optimization of the MBE growth to produce the best mode locking behavior was begun in this project.

A potentially useful direction for future research in this area is the construction of electrically controlled saturable absorbers for active, rather than passive, mode locking. Such structures might be useful to reduce jitter in mode locking repetition rates.

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